Leonardo da Vinci

1452

1519

No man in recorded history exemplifies the inventive capacity of mankind more fully than the 15th-century genius, Leonardo da Vinci. He investigated virtually every field of science and recorded his observations and reactions in thousands of sketches and notes. They contained practical solutions to specific problems of his day, and also envisioned such future possibilities as flying machines, automobiles and automation. No field of endeavor was too small to excite his interest; none so large as to smother his spark.

Since 1951, International Business Machines Corporation's traveling exhibitions of models built according to Leonardo's scientific and technical drawings have been shown in museums, colleges, universities and public libraries throughout the United States. These exhibitions are intended as a spark to create curiosity–the quality that leads man to ask questions about the physical world around him, to dream dreams for its progress, and then to search for the answers that will turn the dreams into reality.

The models have been selected from the company's larger collection to give a brief indication of the extraordinary range of Leonardo's interests and investigations. In order to accommodate diverse institutions, the exhibitions vary in size and content. All the models illustrated in this brochure are included in one or more of the touring shows; no single exhibition contains all of them.

1 Left: Studies of phonemes, *Quad. Anat. IV, fol.* 10*r.*

Fifteenth century Italy was bursting with vitality and vibrant with change. The last vestiges of the medieval world were vanishing. A new age had begun called the Renaissance, or rebirth, because it seemed as if men were suddenly awakening to the wonders of this world, which the Middle Ages had regarded as merely a brief and troubled preparation for the next. During previous centuries few could read and write, and learning had declined. Science was largely considered the domain of alchemists, necromancers and heretics. Men had been content to accept the little they had inherited of what the Greeks and Romans had written about nature and man, rather than looking around them and believing the evidence of their own senses. As a result, knowledge had gained little and lost much during the intervening years. But starting with the Renaissance came a spurt of progress that included Galileo's proof in 1609 of the form of the solar system, and later in the 17th century, Sir Isaac Newton's mathematical demonstration of an ordered universe. It was during this period that the modern world was born.

Leonardo lived at the beginning of this dynamic transition. His observations and experiments contributed much to its development, but his mind soared far beyond, both in time and space. In the stratification of rocks he saw the evidence of the workings of the laws of nature throughout eons of time. In the rippling surface of water he observed the principle of the transmission of energy according to what centuries later came to be called the wave theory.

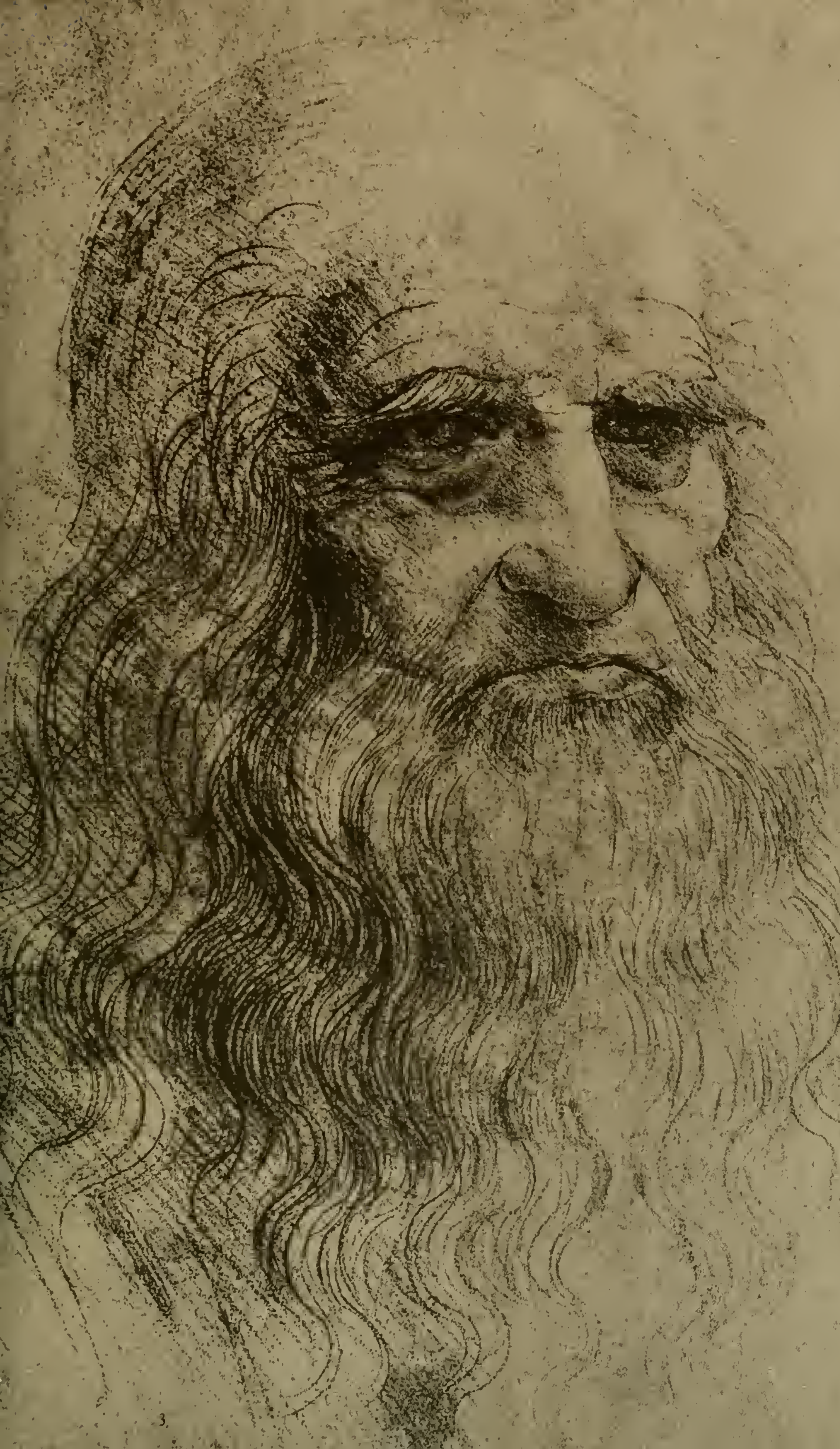
Concerned with accuracy and measurement, he was one of the few to believe that mathematics supplied a certain means of scientific proof and statement, thus anticipating the modern concept of mathematics as the language of science. For him mechanics was "the paradise of the mathematical sciences, because by means of it one comes to the fruits of mathematics."

The many devices, whether practical or theoretical, that he sketched and described in his notebooks, and the models that have been made to illustrate a number of them, are demonstrations of this belief.

Where others saw only a bewildering diversity, Leonardo saw the similarities beneath the surface. He analyzed things in terms of function. In the structure and working of the bones and muscles of men and animals he recognized the same mechanical principles that applied to machines. In an age still haunted by medieval superstition, he could write that "a bird is an instrument working according to mathematical law, which... is within the capacity of man to reproduce..." He believed that man could understand and use the forces of nature.

Leonardo was an artist by instinct as well as by training. For him, vision was the key to knowledge because it is the primary means of perception. Therefore, he considered the new science of perspective an invaluable tool, and illustrated a book on the subject written by his friend, the learned monk Fra Luca Pacioli. By means of his drawings, Leonardo had the genius to show ideas and principles, and their application, that could not be expressed in words. "The more minute your description," he wrote, "the more you will confuse the mind of the reader, and the more you will lead him away from the thing described. It is necessary therefore... to represent and describe." And that is what he did throughout the innumerable pages of his notebooks, started when a young man in Florence and kept up till he died at Amboise. They became a treasury of information and observation, and of theory and speculation, that has fascinated every generation since his own day.

Of all the cities of Renaissance Italy, none was more brilliant than Florence, where Leonardo spent the years of his youth and early manhood. Under the rule of Cosimo de' Medici and his grandson Lorenzo the Magnificent, the city flourished culturally as well as



3.

Presumed self-portrait, *Royal Library, Turin.*

5 Studies for the Last Supper, *Academy, Venice*

commercially. Its university was enriched by the talents of scholars from all over Europe. Its architects ornamented its streets with churches and palaces. Its artists filled them with paintings and sculptures, and carried out commissions for kings and cardinals.

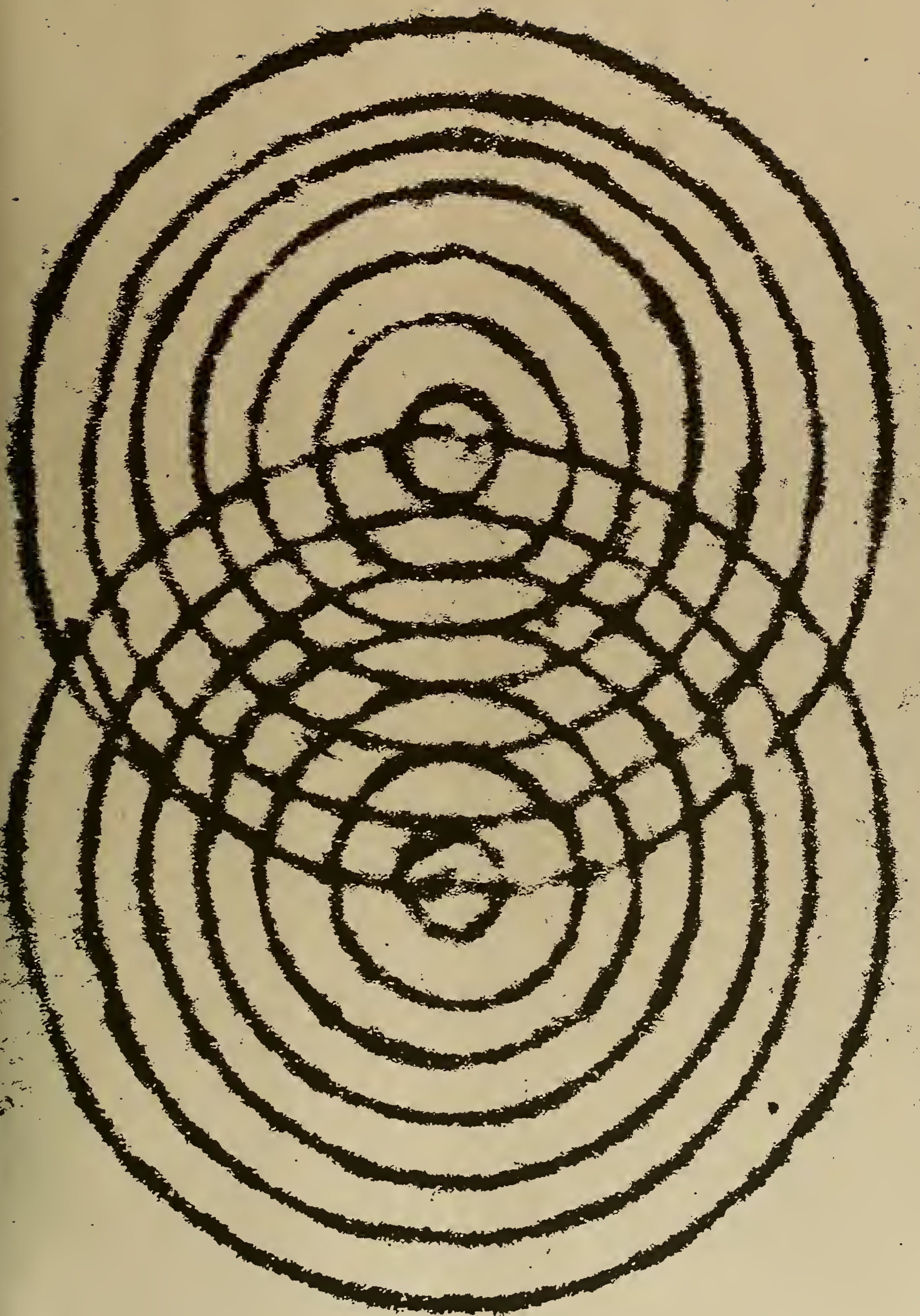
When about 14, Leonardo was apprenticed to the city's leading sculptor, known to history as Verrocchio, or "True-Eye," a nickname given by admiring friends. Like all the leading Florentine artists of the period, Andrea Verrocchio was trained first as a goldsmith, thus gaining the precise craftsmanship of that ancient art as a basis for all his other creative work. He was an architect and painter, and a sculptor in stone, wood, wax, plaster and bronze. His shop was a meeting place for artists and those interested in art. There were discussed the latest plays and poems, paintings, sculptures and architectural designs. As one of his apprentices, Leonardo saw and took part in all sorts of work, from the making of surgical and musical instruments to the production of monumental statues and altarpieces.

Leonardo felt all his life the lack of an early knowledge of Greek and Latin. These were the languages of the scholars and poets that surrounded Lorenzo the Magnificent, and also of the ancient authors whose newly rediscovered works were beginning to reveal exciting glimpses of the Classic past. But while others were spending their time with books, Leonardo was gaining in Verrocchio's shop the practical training that allowed him to devote a lifetime to imaginative experiment in all the then known fields of the arts and sciences. Therefore, he used the artist's technique of perspective to record his observations of the first scientific dissections since ancient times, creating the modern sciences of anatomy and comparative anatomy. And he used a sculptor's technique in casting to determine for the first time in history the exact form of the human brain.

By his early twenties Leonardo had become famous as a painter and a sculptor, an accomplished musician, and a powerful athlete with extraordinary coordination. During his boyhood in the little hill town of Vinci, where he was born, he had acquired the interest in the natural world that possessed him throughout his life. His love of animals enabled him to ride horses others dared not mount, and led him to buy cages of songbirds in the marketplace so that he could set them free.

His unusual quickness of eye made it possible to analyze the flight of birds so that he could write the first treatise in history on the subject. He believed that "given the cause, nature produces the effect in the briefest possible way," and devised endless schemes for flying machines on the principle of flapping flight with a flexible wing. His visual keenness allowed him to understand the complex patterns of the flow of water, of which he found evidence in the weathering of mountains and the formation of river beds. He applied this knowledge to his designs for canals and locks and for the hulls of ships.

"If you are alone, you belong entirely to yourself," he wrote, and his extraordinary gifts, the breadth of his interests, and his wide-ranging imagination combined to make him a solitary person. In an age when one could be burned at the stake for holding heretical views, he scorned the orthodox belief that fossils found in rocks were either made by a mysterious action of the stars or left over from Noah's flood. And before the famous Polish astronomer, Nicolaus Copernicus, had completed the formulation of his theory of a sun-centered universe, Leonardo was jotting in his notebook that "the sun does not move," and that "the earth is not the center of the circuit of the sun, nor in the center of the universe..." More than a century later, Galileo was forced publicly to deny the Copernican theory. Leonardo wisely kept such dangerous notions to himself.



7 Transverse waves, *Ms. A. fol.* 61 *r.*

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During his long career as one of the leading engineers of his time, his notebooks were the single and very personal record of his professional secrets and activities. To their pages he confided his observations, thoughts, and dreams of the future. In his neat mirror writing he jotted down the books he read and intended to read, the debts he owed and those due him, the rents derived from his estate near Milan, and the drafts of letters. He made thousands of notes for a series of works that were never completed, on anatomy, painting, sculpture, architecture, water, military engineering, perspective and other subjects.

The notebook pages combine practical machines and devices, such as an air conditioning system for the Duchess Isabella's apartments in the castle in Milan, with curious fables and drawings of deluges and earthquakes that suggest the destruction of the world in an atomic blast. There are designs for machines for such diverse purposes as minting coins, polishing needles, making files, and cutting threaded rods, all showing his preoccupation with mass production and automation. We find also sketches for an ideal city, with canals, and streets at two levels, the lower for vehicles and the upper for pedestrians. There are drawings of a stable with a gravity feed system and of domed, centrally planned churches that almost surely influenced his friend Bramante in the design of St. Peter's in Rome.

The notebooks contain evidence that Leonardo knew how to polish concave mirrors and various forms of lenses for astronomical observation, and the laconic note "to make glasses in order to see the moon large." Though he considered war a bestial madness," his notebooks include innumerable sketches for fortifications and weapons. Among these are a gigantic ballista, or crossbow; a horrendous scythed chariot, a kind of ancestor of the tank, and multibarreled cannon. There are designs for bridges and gears, for flying machines and life preservers, for dredges and diving equipment. But beneath the fantastic variety lies a unity of purpose founded on Leonardo's belief that through accurate observation man can understand the principles of everything in nature.

"All our knowledge," Leonardo wrote, "has its origin in our perceptions." And he was the first to bring an artist's training, imagination and insight to the pursuit of knowledge, which he called "the natural desire of good men." For him, art and science were the same, and their purpose was to lead to truth, to an understanding of the secrets of man and of the universe. In the *Last Supper*, today only a splendid ruin, he disclosed through gesture and expression the inner life of Christ and the Apostles and thus revealed the essential meaning of the event. Similarly, in his scientific drawings analyzing the flow of water he sought to show the forces of nature working according to divine law.

The main task of science during the Renaissance was to recover as much as possible of what had been lost to knowledge during the centuries of the Middle Ages that had shadowed the brightness of the Classic World, with its rich heritage of science and philosophy, and of literature and art. The Renaissance was thus a period of synthesis, of putting things together and relating them. Then, it was possible for men to hope to master the whole range of human knowledge. Perhaps more than anyone since the ancient Greeks, Leonardo came closest to realizing that lofty ambition. He lived at an expansive moment in history, an age of discovery. He shared with his contemporaries, Christopher Columbus and Amerigo Vespucci, as with Nicolaus Copernicus, Galileo Galilei, and the long line of the world's greatest thinkers down to our own day, an adventurous spirit of exploration, and a dream of a limitless future for man.

Richard McLanathan

10 Leonardo's aerial screw or helicopter, *Ms. B. fol.* 83 *v*

Parachute:

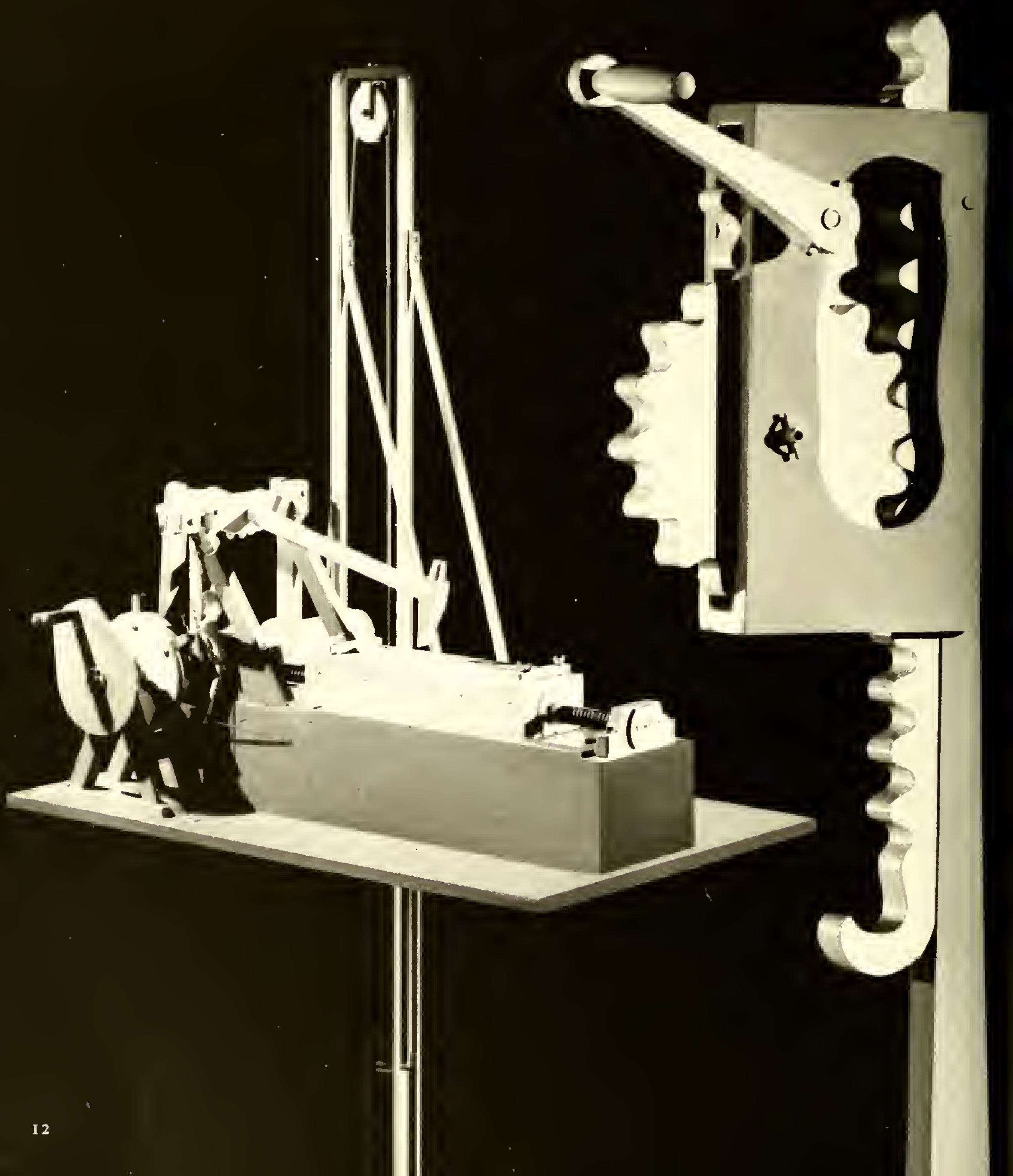
"If a man have a tent made of linen of which the apertures have all been stopped up, and it be twelve braccia across and twelve in depth," Leonardo wrote, "he will be able to throw himself down from any great height without suffering any injury."

Helicopter:

Leonardo was fascinated with the form of the spiral, which often appears in nature and is involved in the principle of the screw. His helicopter takes the form of an aerial screw, following the example of a device earlier brought to Europe from the Far East in the form of a children's toy.

File Cutter:
Though there is no record that such a machine was built, it is workable in principle. It involves two ideas significant for the future: first, the use of a threaded shaft to control automatically the movement of the file blank so that it may be evenly scored by the trip-hammer, and second, the use of a falling weight as a source of power. The latter is a clockwork mechanism here applied to an industrial use. Therefore, the machine represents a step toward automation, an idea that recurs in Leonardo's notebooks, but was not to be realized for centuries.

Jack:
Since the lifting of weights is one of the most common problems of the engineer and mechanic, Leonardo gave it much study, designing devices using the principle of the pulley, the screw and, as here, a series of gears in a form that anticipates a modern automobile jack.

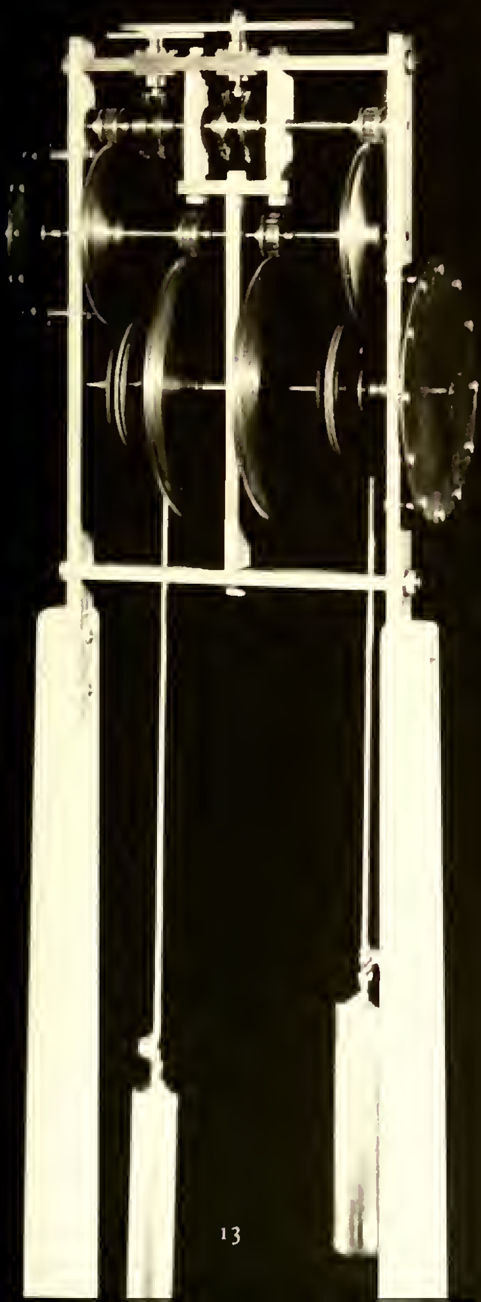


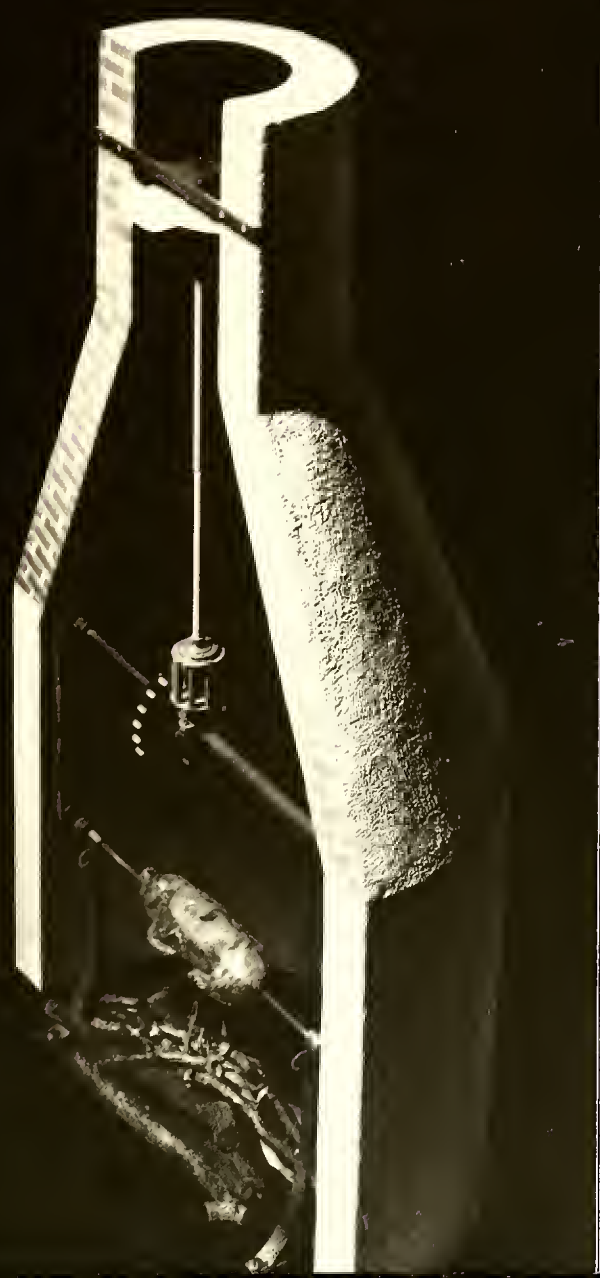
Clock:

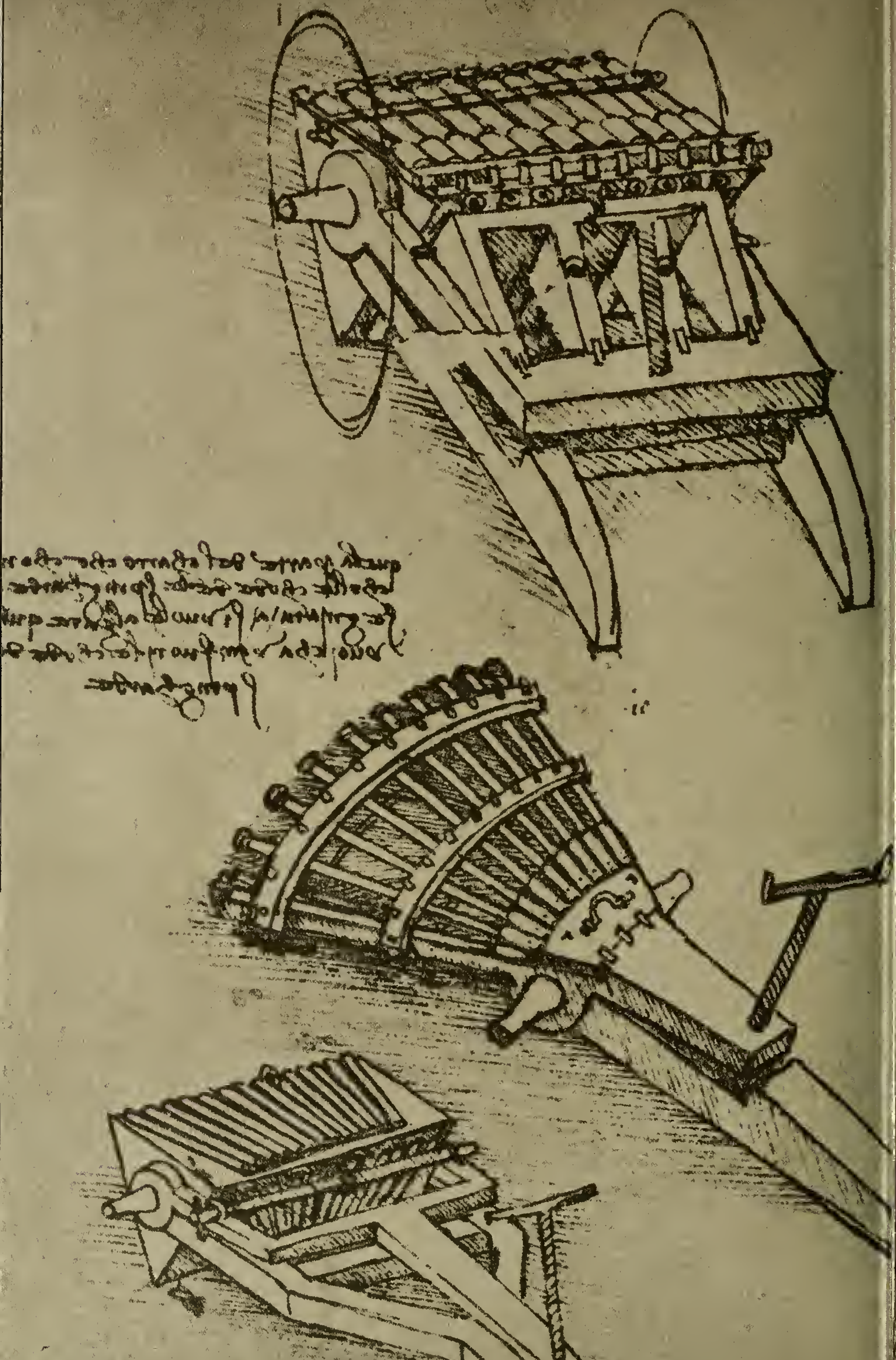
For greater accuracy, Leonardo designed a clock mechanism with two separate trains, one for minutes and the other for hours, each complete with escapement, gears and weight. Weight-driven mechanisms had been associated with clocks for so long that they had come to be regarded as exclusively for this purpose, but Leonardo used them for increased automation of other machines, such as his file cutter. Clocks registering both hours and minutes had become sufficiently accurate during the 15th century so that they were even occasionally used in astronomical observations.

Automatic Turnspit:

Such devices were known in various automatic and semiautomatic forms since ancient times. In this version, Leonardo shows his knowledge of the principle of convection, since the spit turns through the action of the rising hot air on the fan set in the chimney flue. In another turnspit, he applied the clockwork mechanism of the falling weight to turn the spit, using a fan vaned with goose feathers as a governor.

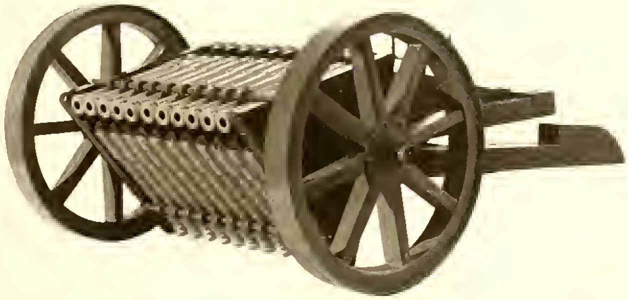




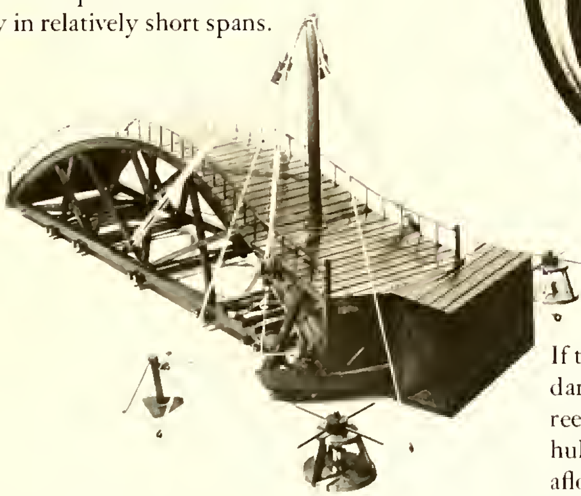


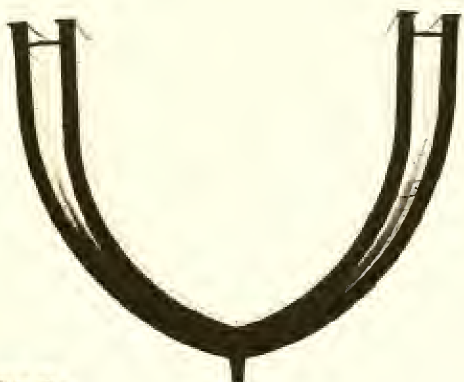
14 Multibarreled cannon and machine gun, *Cod. Atl., fol. 56v-a.*

Triple-Tier Maehine Gun:
There are eleven barrels in eaeh tier. While one is fired, another tier is loaded, and the third eools. This weapon, like others Leonardo designed, shows him eonstantly attempting to aehieve greater fire power.



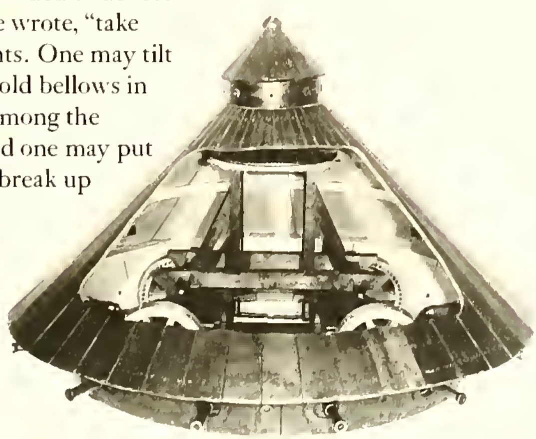
Rotating Bridge:
Designed to eonneet an island stronghold with the mainland, this bridge eould be swung aeross a stream or moat and baek again by means of windlasses. Swing bridges have proven to be praetieal only in relatively short spans.



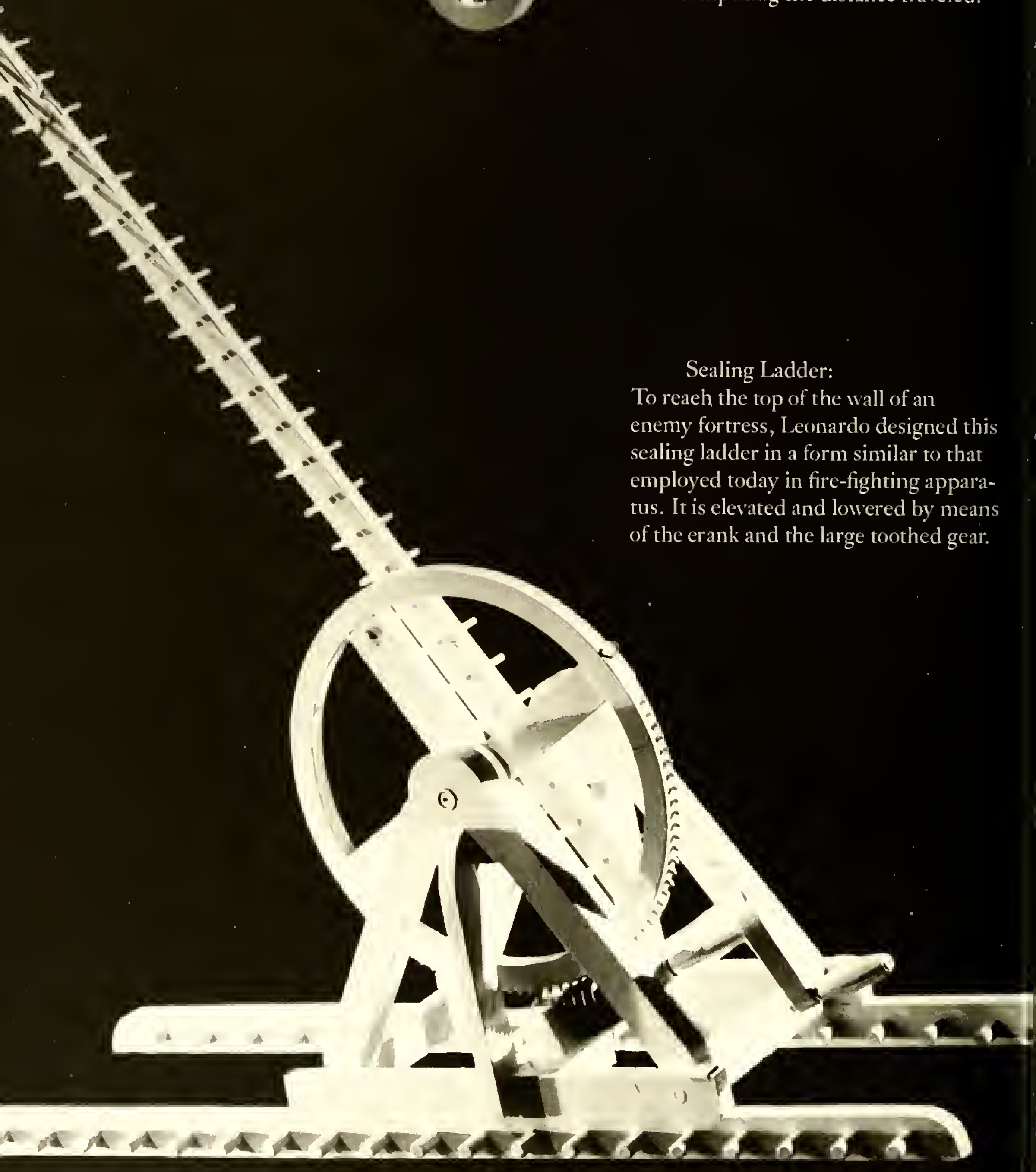


Double-Hulled Ship:
If the outer hull of sueh a vessel were damaged, either by enemy aetion or by reefs or floating wreekage, the inner hull, still intaet, would keep the ship afloat. In more reeent times both double hulls and the division of the interior of the vessel into separate eompartments by watertight bulkheads have earried Leonardo's idea forward.

Military Tank:
Leonardo designed this aneestral version of the tank to earry heavy fire power and be driven by men working the enelosed wheels with eranks. Its turtle-like eover was intended to defleet enemy fire. "These," he wrote, "take the plaee of the elephants. One may tilt with them. One may hold bellows in them to spread terror among the horses of the enemy, and one may put earabineers in them to break up every eompany."

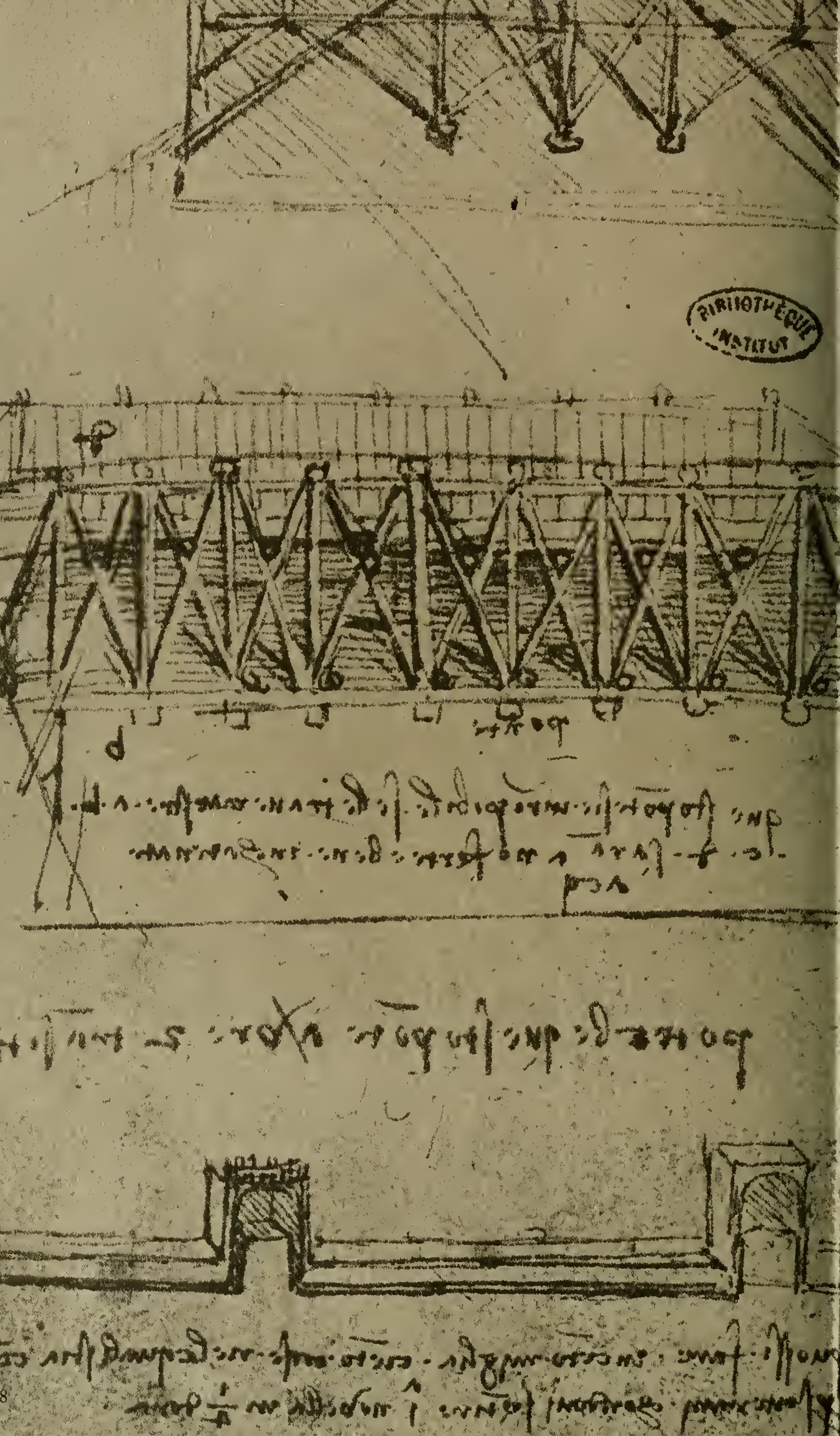


Odometer:
Leonardo often made maps, both for military purposes and for canal construction. He therefore designed several distance-recording devices, including a pendulum type pedometer and odometer. The latter is one of several variations on an instrument described by the Roman architect and engineer, Vitruvius, whose works were rediscovered early in the Renaissance. It was geared to drop a pellet into a box for a given number of revolutions of a wheel, thus computing the distance traveled.



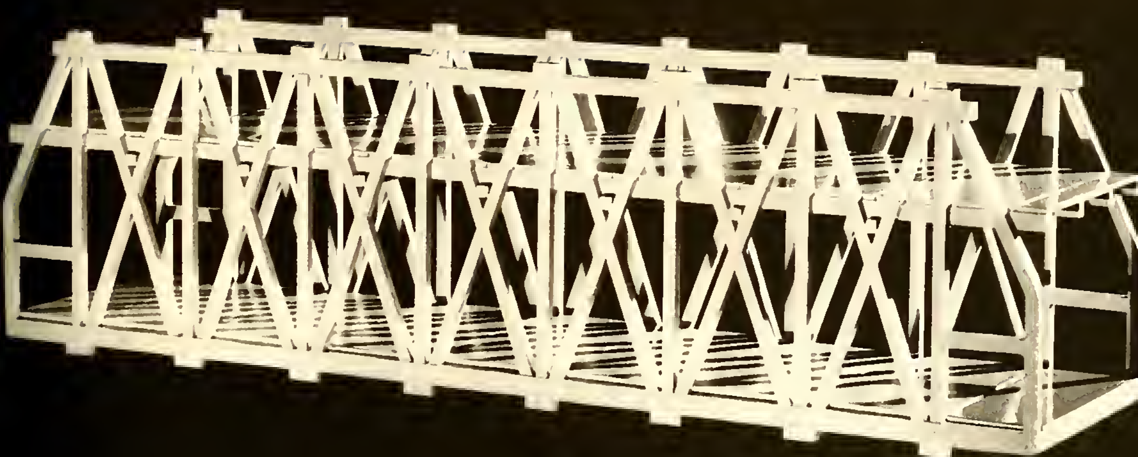
Scaling Ladder:
To reach the top of the wall of an enemy fortress, Leonardo designed this scaling ladder in a form similar to that employed today in fire-fighting apparatus. It is elevated and lowered by means of the crank and the large toothed gear.

Spindle-Shaped Hull:
Intensive study of the action of water and the shapes of fish led Leonardo to design hulls of greater stability and less friction than the round-bottomed vessels then generally in use, and somewhat similar to certain sections of modern racing hulls. Each side of the model illustrates a different design, developed from an experimental and functional point of view similar to that of modern engineering and marine architecture.

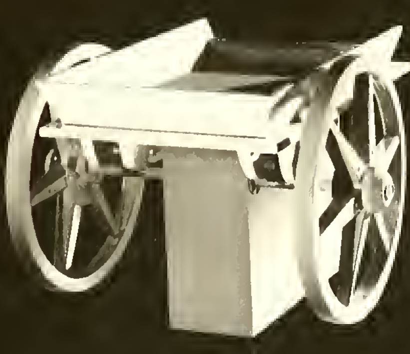


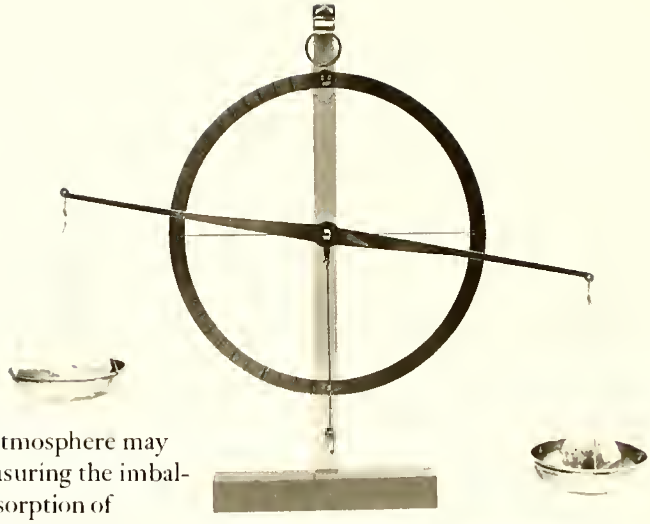
Wooden bridge, *Ms. B, fol. 23r*

Two-Level Bridge:
In reserving the upper level for pedestrians and the lower for vehicles, Leonardo used the same idea for traffic control that appears in his plans for an ideal city in which entire streets were thus restricted. The truss is similar to a type used in bridges since the early 19th century.

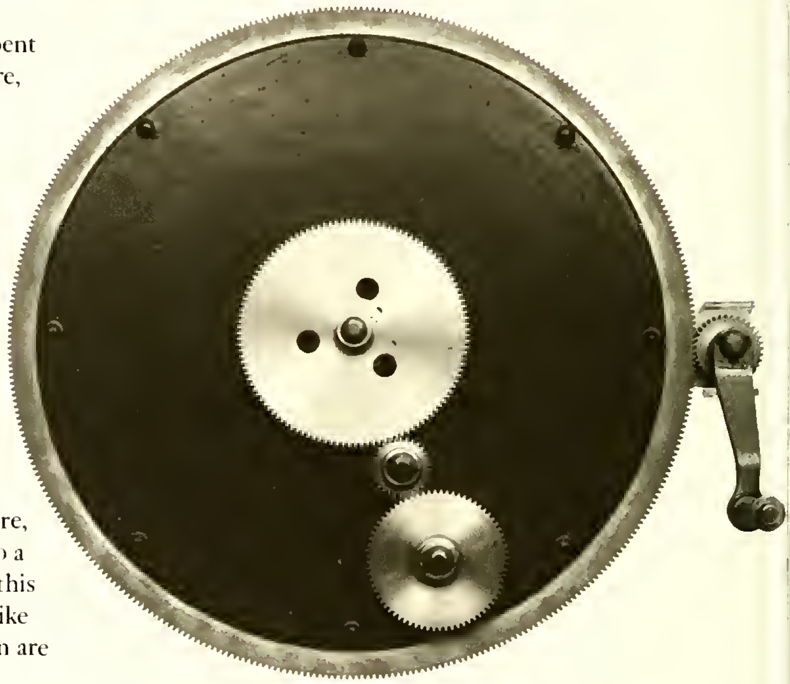


Roller Bearings:
Leonardo carried out many experiments with friction, including a transmission system. He found that roller bearings, as here applied to the revolving axle of a wagon, were excellent "friction removers," a function they continue to fulfill in many different situations.





Hygrometer:
The humidity of the atmosphere may be determined by measuring the imbalance caused by the absorption of moisture by the cotton, which, when dry, is equal to the weight on the other side of the scale. Leonardo spent much time studying the atmosphere, both as an artist and as a scientist, recording in drawings many of the effects he observed.

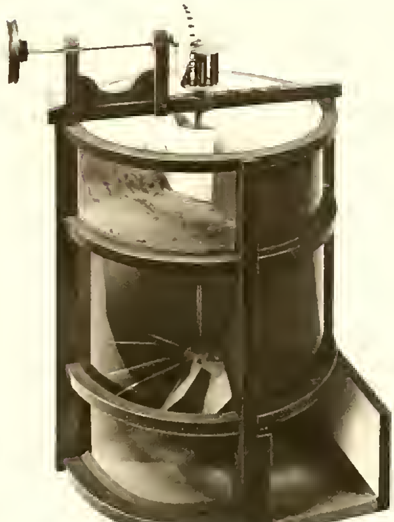


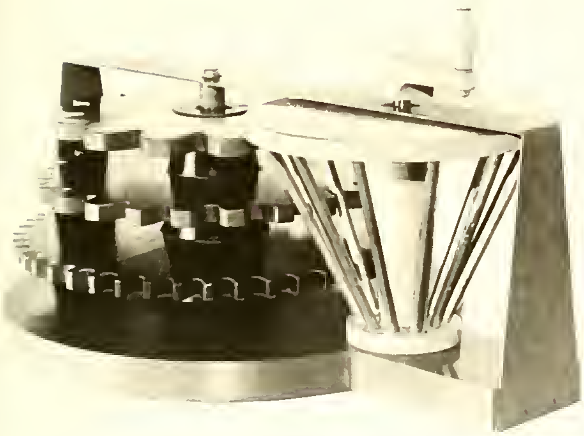
Gear Study:
Drawings of gear systems recur in Leonardo's notebooks, often, as here, theoretical rather than applicable to a specific device. Similar systems to this later appeared in clocks and clock-like mechanisms, and variations of them are in common use today.

Printing Press:
Gutenberg is generally credited with the invention of the printing press nearly a half century earlier, in about 1448, but Leonardo seems to have been the first to attempt a basic improvement by making a press operable by one man instead of several. A turn of the screw draws both type bed and paper under the platen and supplies the pressure to print, while a reverse turn releases the bed. The first practical applications of such improvements had to await the early 17th century.

Wire-Testing Device:
Like modern scientists and engineers, Leonardo wanted as precise information as possible about the properties and capacities of materials so that they could be used more effectively and economically. By weighing the basket after the breaking of the wire had automatically shut off the flow of sand, he could determine the tensile strength of the wire.

Hydraulic Screw:
The water turbine, an encased waterwheel, was developed in the early 19th century. Leonardo's horizontal impulse wheel, driven by the weight of falling water, and his hydraulic screw were important steps in this direction. Like the turbine, the hydraulic screw works with greater efficiency and a smaller water supply than the older overshot or undershot type waterwheels.





Variable Speed Drive:
This is another theoretical gear system that anticipates a number of modern applications. Meshing of three cogged wheels of different diameters to the same lantern wheel produces three different speeds of rotation, a principle used in the transmission of the modern automobile.

Inclinometer:
Leonardo always sought the greatest possible accuracy, and therefore was constantly designing devices for measurement, such as this instrument to determine the degree of incline of a given surface by the relation of the plumb bob to the concentric scale inscribed below its mounting. The accurate figuring of slight gradients was of great importance in laying out canals.

His Life	His Times
1452: In April Leonardo is born at Anchiano, near Vinci, in Tuscany, the illegitimate son of Ser Piero da Vinci, a young lawyer, and Caterina, a country girl.	
	1453: The fall of Constantinople to the Turks ends the Eastern Empire after a thousand years.
	1464: Cosimo de' Medici dies and is succeeded by his son, Piero.
1469: Leonardo is living in Florence, apprenticed to Andrea Verrocchio.	1469: Giuliano and Lorenzo de' Medici inherit the leadership of Florence on the death of their father, Piero.
	1471: Pope Sixtus IV starts to reign.
1472: Completes Verrocchio's painting of *The Baptism of Christ*, now in the Uffizi Museum in Florence, and is admitted to the Guild of St. Luke as a painter.	
1473: Draws a landscape of the Arno valley on August 5th, his first dated work.	1473: Nicolaus Copernicus, the famous astronomer, born in Poland.
	1475: Michelangelo Buonarroti born at Caprese in Tuscany.
1476: Still in Verrocchio's studio as an assistant and collaborator.	
	1478: The Pazzi conspiracy to overthrow the Medici: Giuliano is murdered at high mass in the cathedral, but Lorenzo the Magnificent survives, though wounded; war with Naples and the Pope follows.
1480: He gains the patronage of Lorenzo de'Medici, the ruler of Florence.	
1481: Commissioned to paint an *Adoration of the Kings* for the monastery of S. Donato a Scopeto near Florence. Never completed, it is now in the Uffizi.	
1481-2: Goes to Milan as painter and engineer to Duke Ludovico Sforza, and to sculpture an equestrian monument of Francesco Sforza, the Duke's father.	
1483: Contracts to paint *The Virgin of the Rocks* now in the Louvre; a later version is in the National Gallery in London.	1483: Raphael Sanzio born at Urbino.
	1484: Pope Innocent VIII starts to reign.
1487: Designs the pageant of *Il Paradiso* with its revolving stage, and works on designs for the central tower of the cathedral of Milan.	
1488: About this time paints the portrait of Cecilia Gallerani, identified as *The Lady with the Ermine* in Cracow.	1488: Verrocchio dies in Florence.
1489: Works on anatomical research.	
1490: Recommences work on the equestrian monument.	
	1492: Columbus' first voyage to the New World; Lorenzo the Magnificent dies and is succeeded by his ineffective son, Piero; Rodrigo Borgia elected Pope as Alexander VI.
1493: The full-scale model of the monument is exhibited at the time of the wedding of Bianca Maria Sforza and the Emperor Maximilian.	
	1494: Charles VIII of France invades Italy, briefly occupies Florence, and, the following year, Naples. The Dominican monk, Savonarola, institutes a reform government in Florence after the banishment of the Medici.
1495: Starts work in the refectory of S. Maria delle Grazie in Milan on *The Last Supper,* which is nearly finished by the end of 1497.	
1498: Paints the Sala delle Asse in the Sforza Castle.	1498: Savonarola hanged and burnt in the Piazza della Signoria in Florence.

Spray of Oak Leaves with Cluster of Acorns, *Royal Collection, Windsor.*
Reproduced by gracious permission of Her Majesty Queen Elizabeth II.

His Life

1499: In April Duke Ludovico gives Leonardo a vineyard near Milan. In December Leonardo flees Milan at the Duke's downfall.

1500: Visits Mantua, where he draws the portrait of the Duchess Isabella d'Este. Goes to Venice in February and returns to Florence in the spring.

1501: At work on *The Madonna and Child with St. Anne*, the drawing for which is now in the National Gallery in London, while the painting is in the Louvre. He is also at work on the lost *Madonna with the Yarn Winder* and has several pupils.

1502: Military Engineer for Cesare Borgia, son of Pope Alexander VI and Captain-General of the Papal Armies.

1503: Begins the cartoon for the fresco of *The Battle of Anghiari* commissioned by the government of Florence for the Grand Council Chamber of the Palazzo della Signoria. Works on the *Mona Lisa*, now in the Louvre, and carries on dissections and anatomical studies.

1504: One of those appointed to decide the best place for Michelangelo's statue of David.

1506: Obtains permission from the Florentine government to leave the *Battle of Anghiari* fresco, never to be finished, and returns to Milan to work on projects for Charles d'Amboise, the French governor of the city. Designs another equestrian monument, for Gian Giacomo Trivulzio.

1507: Appointed painter and engineer to King Louis XII of France, and in September returns to Florence.

1508: Back in Milan for further anatomical studies and other research.

1510-11: Anatomical research with the young Marc Antonio della Torre, who came to be considered the greatest anatomist of his time.

1513: Leaves Milan for Florence, then goes to Rome, where he is given apartments in the Belvedere of the Vatican under the patronage of Giuliano de'Medici, Duke of Nemours, son of Lorenzo the Magnificent and brother of Pope Leo X.

1516-17: To France as "First Painter and Engineer to the King of France"; lives in the manor of Cloux, gift of Francis I, who holds court at the Chateau of Amboise nearby.

1517: Visited by the Cardinal of Aragon, who sees his paintings and many manuscripts.

1518: Reception at Cloux for the wedding of the King's niece to Lorenzo de' Medici, Duke of Urbino and brother of Leo X.

1519: Leonardo dies at Cloux on May 2nd and is buried in the church of St. Florentine in Amboise.

His Times

1499: The French under Louis XII invade Italy and capture Milan. Michelangelo completes his *Pieta* in the Vatican.

1500: Duke Ludovico counterattacks, loses, is captured by the French and imprisoned in the Chateau of Loches, where he dies in 1508.

1501-2: Second voyage of Amerigo Vespucci to the New World, the published account of which led to the naming of America after him.

1503: Pope Julius II, patron of Raphael and Michelangelo, starts to reign.

1504: Michelangelo starts work on the cartoon for a fresco for the Palazzo della Signoria in Florence, commissioned as a pendant to Leonardo's *Battle of Anghiari*; neither reaches completion.

1506: Construction begins on St. Peter's in Rome.

1508: Michelangelo starts work on his Sistine Chapel frescoes.

1512: Michelangelo completes the Sistine ceiling, and Raphael finishes his frescoes of *The School of Athens* and *The Disputation of the Sacrament* in the Vatican.

1513: Giovanni de' Medici, son of Lorenzo the Magnificent, elected Pope as Leo X.

1515: Francis I succeeds to the throne of France.

1516: Giuliano de' Medici, Duke of Nemours, son of Lorenzo and patron of Leonardo, dies.

1517: Raphael starts work on *The Transformation*, left unfinished at his death at 37 in 1520. Michelangelo in Florence working on the unfinished facade of S. Lorenzo and planning the Medici Chapel.

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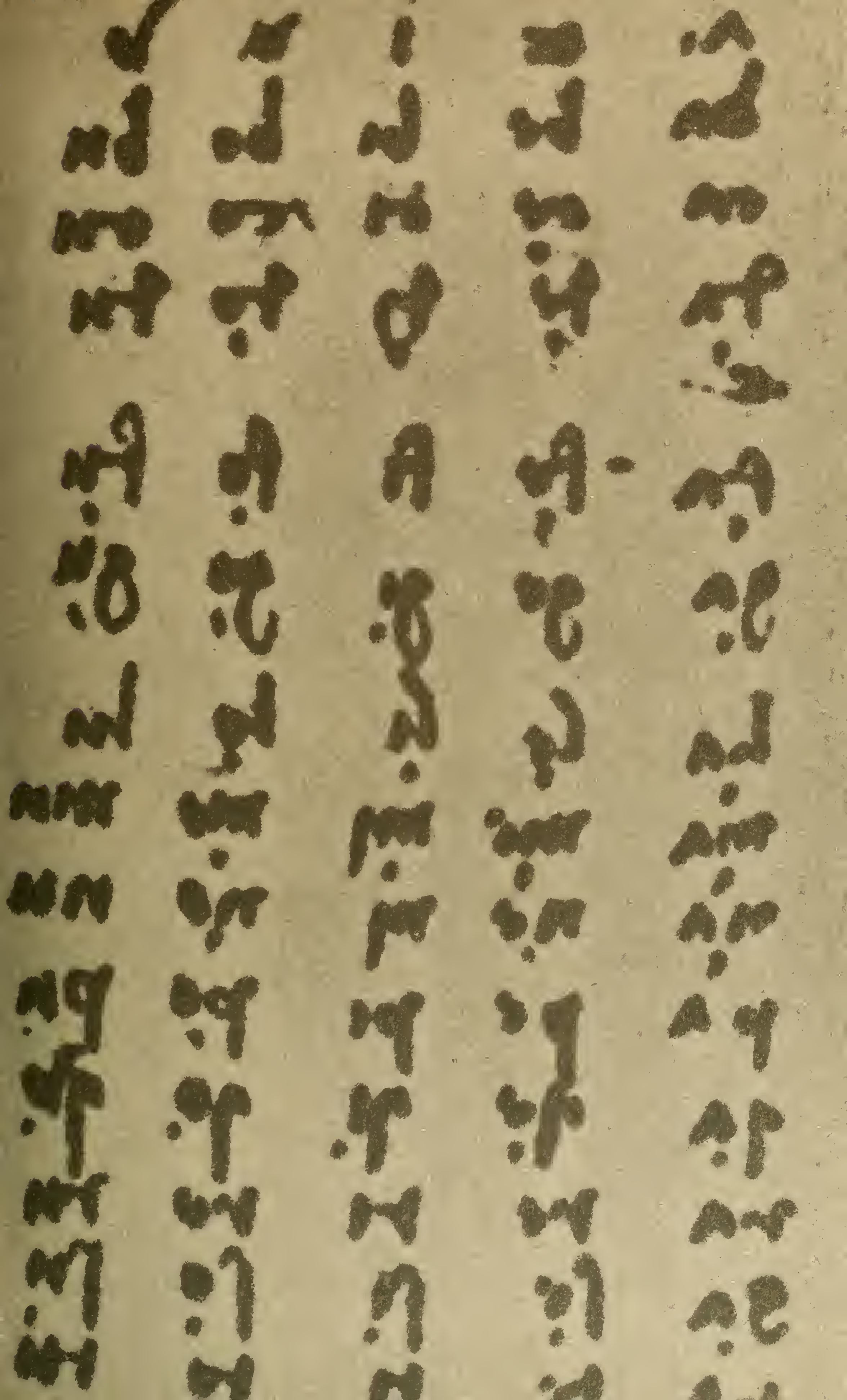

International Business Machines Corporation
Old Orchard Road
Armonk, New York 10504